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CHARACTERISTICS OF A PHOTOIONIZATION CHAMBER FOR THE VACUUM ULTRAVIOLET

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Papers No. WC 17 and WC 19 presented at the Los Angeles meeting of the Optical Society of America, October 18, 1961.

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SPECTRALLY SELECTIVE PHOTODETECTORS FOR THE MIDDLE AND VACUUM ULTRAVIOLET

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Paper No. WC 17 presented at the Los Angeles Meeting
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The need for photodetectors which efficiently detect radiation in the middle and vacuum ultraviolet but which are relatively insensitive to near ultraviolet and visible light has led in recent years to the development of a variety of spectrally selective ultraviolet photodetectors. H. L. Sowers has reported on a middle UV detector in paper WC 15 of this meeting. In this and the following two papers, WC 18 and WC 19, we shall review some of the work done on other improved photodetectors since our report to the Columbus meeting of the Optical Society four years ago and the Fifth International Commission for Optics Meeting of 1959.[1] We define the middle UV as extending from 3000 to 2000 Angstroms and the far or vacuum UV as extending from 2000A to the shorter wavelengths.

In this first paper, WC 17, we shall review the spectral distribution of photoelectric yields of the surfaces of various phototubes and photomultipliers prepared by both industrial and governmental laboratories. In the second paper, WC 18, spectral response, gain and noise characteristics of new commercial cesium telluride photomultipliers will be discussed in detail. In the third paper, WC 19, the characteristics of photoionization chambers are given.

Selective photoemitting surfaces may be of the pure metal types, as has been reported by Rentschler[2] and others since the 1920's and which have been studied in the vacuum UV region by Watanabe and Hinteregger[3] and by Walker, Wainfan and Weissler[4] and others since the 1950's. Such pure metal surfaces generally

have low quantum efficiencies in the middle UV. a review of these researches in photoelectric emission from solids, emphasizing the vacuum UV, is contained in a chapter by Weissler in Vol. XXI of Handbuch der Physik.

The photocathode may also be a composite surface such as the well known Cs-Sb or the selective alkali tellurides having high yields as reported in 1953 by Apker[5] and his colleagues of the GE Research Laboratory. Since then Harper and Choyke, Roderick, Kretschmar, Sowers, Linden, Sommer, Causse and others have prepared alkali telluride opaque and semi-transparent surfaces. In some cases their photoemissive properties were studied at the Naval Research Laboratory in the 1950's and in other cases more recently at our own laboratory.

Figure 1 gives the spectral response (photoelectric yield) of several photocathode materials in the vacuum and middle ultraviolet regions from 1000 to 3500 Angstroms. The extreme right curve shows the short wavelength portion of the response of the well known Cs-Sb, 1P21 photomultiplier which has a glass envelope and is used primarily in the visible region. By employing a UV transmitting glass, Corning 9741, the 1P28 photomultiplier, introduced some 15 years ago, extends the Cs-Sb range by well over 1000A, or into the beginning of the vacuum ultraviolet. By using a quartz enveloped Cs-Sb photosurface, which we described in the Journal of the Optical Society of America over 10 years ago[6], the range is extended to approximately 1600A. This tube became commerically available several years ago as type 7200. Recently we have examined Cs-Sb with a calcium fluoride window. The figure shows the further extension of the comparatively flat, high quantum yield of Cs-Sb down to 1225A with this phototube. The far ultraviolet windows are identified in these figures by being enclosed in a box.

In cases where high yields, selective to wavelengths below 3000A are desired, a photosurface such as Rb-Te is advantageous. If one finds it necessary to limit the response of a detector to the vacuum UV then a material like Cu-I is useful. Note the high yield of this Cu-I photosurface. Finally in Figure 1 there are shown in dashed lines for comparison purposes, two examples of relatively narrow response vacuum UV photoionization detectors which will be described in the later paper, WC 19. In the successive figures we shall discuss some of the composite cathodes.

In Figure 2 there are shown two groupings of Rb-Te opaque cathodes. Curves 4 and 5 represent the average of the extremes of many tubes prepared by Roderick of GE. Note their high efficiencies at 2500A. On the other hand, the opaque surfaces prepared by Kretschmar of Naval Ordnance Laboratory Corona, while exhibiting lower yields, provide higher selectivity. This may be due to little or no excess rubidium. Curve 1, for example, refers to a photocathode having a yield of 7% at 2537A and a rejection ratio of 10^3 over the narrow wavelength interval 2900-3300A.

In Figure 3, we compare a variety of Cs-Te cathodes. It should be mentioned here that we have found no major differences between rubidium and cesium telluride cathodes with respect to either quantum yield of rejection ratios. However, there is preference by the manufacturers in the preparation of the cesium telluride over the rubidium telluride. Accordingly, efforts this past year have been directed towards the cesium compound. The curves marked XCD-12 and FW 157-1 show the spectral response of sapphire windowed opaque photodiodes. The curve marked 5883 refers to the opaque cathode of a 13 stage photomultiplier with LiF window[7]. Note that better than 10% yield is achieved with these opaque cathodes, whereas

with the two lower curves numbered 151 and 152, which refer to semi-transparent photocathodes in a 14 stage photomultiplier, the yields are considerably lower. It is not clear with the limited data on hand whether this is due to a conductivity problem or incomplete photon capture. On the other hand a semi-transparent cathode just behind the front window results in far better optical coupling than is possible in recessed opaque cathodes. This is frequently an important consideration in application.

In Figure 4 we move to the higher work function materials but maintain the same scales. Curve number 6 refers to the earlier work by Taft and Apker who studied various iodide compounds evaporated on opaque metallic discs. Curve number 3 represents our recent measurements of spectral distribution of yield from Cs-I prepared by Sommer. Here the photocathode is deposited on a conducting substrate of thin tungsten immediately behind the LiF window which makes possible, again, convenient end-on coupling. The two curves number 3 and 6 are quite similar. The slightly lower yield at wavelengths greater than 1400A might be attributable to a transmittance loss in the tungsten conducting substrate. More work is needed on the subject of the effect of semi-transparent conducting substrates. Curves 1, 2 and 5 are reproductions of the work of Taft and his colleagues and are shown here for comparison and for suggestion of surfaces which should be considered if shorter wavelength cut-offs are of interest. The Copper Iodide, Curve 4, is discussed along with the curves of Figure 5.

In Figure 5, for the first time in this sequence of curves, we have changed the scales so that nine orders of magnitude may be displayed. Curve 1 is the familiar Cs-Sb, comparatively flat with a quantum yield of 10%. Curve 2 is the Sommer Cs-I surface already discussed. However, here we

can show that at 2537A the absolute yield is only 7 X 10^{-6}. This was measured with a calibrated low pressure mercury arc. Curve 3 is a result of our recent measurements of a Cu-I semi-transparent surface on tungsten deposited on a LiF window which was prepared by Sommer. This response is similar to that of his Cs-I tube, curve 2, except for the much improved long wavelength rejection ratio which is at least 7 orders of magnitude between 1849A and 2537A. The upper limit of yield at the latter wavelength we determined as less than 10^{-9}. We compared these measurements with the results reported in 1960 by Shuba and Smirnova[8] who estimated a quantum yield of 10^{-1} at the short wavelengths but only a 6 order of magnitude rejection ratio. D. W. Turner[9] of Imperial College reported in 1957 a copper iodide photoemitter with a cut-off at 2300A (although he does not define cut-off) and a peak yield somewhere between 10^{-2} and unity. Copper Iodide thus makes a useful detector for spectroscopic studies in the vacuum ultraviolet not only because of high yield but because it makes negligible the effect of scattered light, derived primarily from the longer wavelength emission of the hydrogen or other gaseous discharge tubes generally used with vacuum monochromators. It is also interesting to compare copper iodide with nickel, Curve 4 and 4a, which was obtained by combining middle and vacuum UV measurements made in 1953 as shown. Cu-I should be far more advantageous in this region than nickel. Up to now nickel, and other similar metal photocathodes were about the only detectors in this region which were readily available. Finally one should also compare the Cu-I efficiency with that of tungsten, curve 5. The open window Bendix photomultiplier, with tungsten cathode, used extensively by Hinteregger and recently by Behring and Neupert at our laboratories, is advantageous below 1000A.

In Figure 6 we show photographs of various photodiodes which we have studied recently. The ITT photodiode shown at the extreme right has been flown recently in an Aerobee-Hi sounding rocket as part of a solar flux photometric experiment in the middle ultraviolet. The phototube third from the left, made by Kretschmar at the Naval Ordnance Laboratory in Corona, has proved very useful in laboratory radiometry.

Figure 7 shows some of the photomultipliers studied. (See Figure captions.)

Time does not permit any further discussion here of all the various configurations and surfaces examined by us. We are indebted to many industrial and government labs for their preparation of the various photodetectors. Time does not permit, either, a thorough discussion on relative and absolute calibration. Briefly, relative curves of the distribution of photoelectric yield of the various surfaces were obtained by using a McPherson 1 meter grating monochromator and the double monochromator of the Cary spectrophotometer. By comparison of the cathode response with the response of sodium salicylate, which is considered to have a relatively constant quantum yield over the wavelength regions considered here, a true relative response is obtained. These relative response curves were put on an absolute basis by using a calibrated mercury arc line at 2537A and intense lines of other discharges.

Figure 8 then is a summary of measurements we have made during the past year on currently available window and filter materials. Curves 7, 8 and 9 are useful in subtractive filter photometry. The other materials are useful as detector windows or as a supplementary window to narrow the photodetector spectral band. Note the two curves numbered 5 which, representative of most crystal windows, indicate that the UV transmittance qualities can vary greatly from crystal to crystal.

Finally there is presented in Figure 9 a summary table. The upper figure in each box refers to the wavelength at which the response is 50% of maximum and the lower figure is the wavelength at 1% of maximum. The shaded area indicates a calculated or averaged value, whereas the clear areas indicate actual measured tubes. The intention is to indicate some of the wide variety of possible photodetector combinations with or without dispersion optics which we are or will be using in our space astronomy and geophysics experiments from rockets and satellites.

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Captions

Figure 1: See separate sheets.

Figure 2: Spectral response curves of rubidium telluride opaque photocathodes.

Figure 3: Spectral response curves of cesium telluride photocathodes. The upper curves refer to opaque and the bottom two curves to semi-transparent cathodes.

Figure 4: Spectral response curves of a variety of high work function cathodes for the vacuum ultra-violet.

Figure 5: Spectral response curves of a variety of photocathodes showing the high rejection of some of the iodide compounds at longer wavelengths. The advantage of the relatively high yield composite photosurface over the lower yield pure metals is also evident.

Figure 6: Photodiodes examined at the Goddard Laboratories. (l-r) CBS, Cs-Sb with Sapphire; Westinghouse, sample, Cs-I with LiF; Kretschmar of Naval Ordnance Lab Corona, Rb-Te with 9741 glass; RCA, Cs-Te with LiF; ASCOP, Cs-Te with LiF; ASCOP, Cs-Te with sapphire; ASCOP, bare tube; ITT, Cs-Te with sapphire.

Figure 7: Photomultipliers examined at the Goddard Laboratories. (l-r) EMI, 6256b; RCA, 1P28; RCA 7151C; ASCOP, 541F; ASCOP, bare tube; RCA experimental model; CBS, CL1067.

Figure 8: Window transmittance cut-offs in the UV region. The two curves numbered 5 indicate the variation in UV transmission qualities of commercial materials.

Figure 9: Table indicates the variety of spectral response regions available by combining different window and cathode materials. The second column from the left gives the short wavelength cut-off, the remaining columns give the long wavelength cut-off. The upper number gives the wavelength where the response is 50% of the maximum response, the lower number gives the wavelength at 1%. Boxes with double lines indicate calculated or averaged values.

Figure 1: Shown here are spectral responses (photoelectric yield) of several photocathode materials in the vacuum and middle ultraviolet wavelength regions.

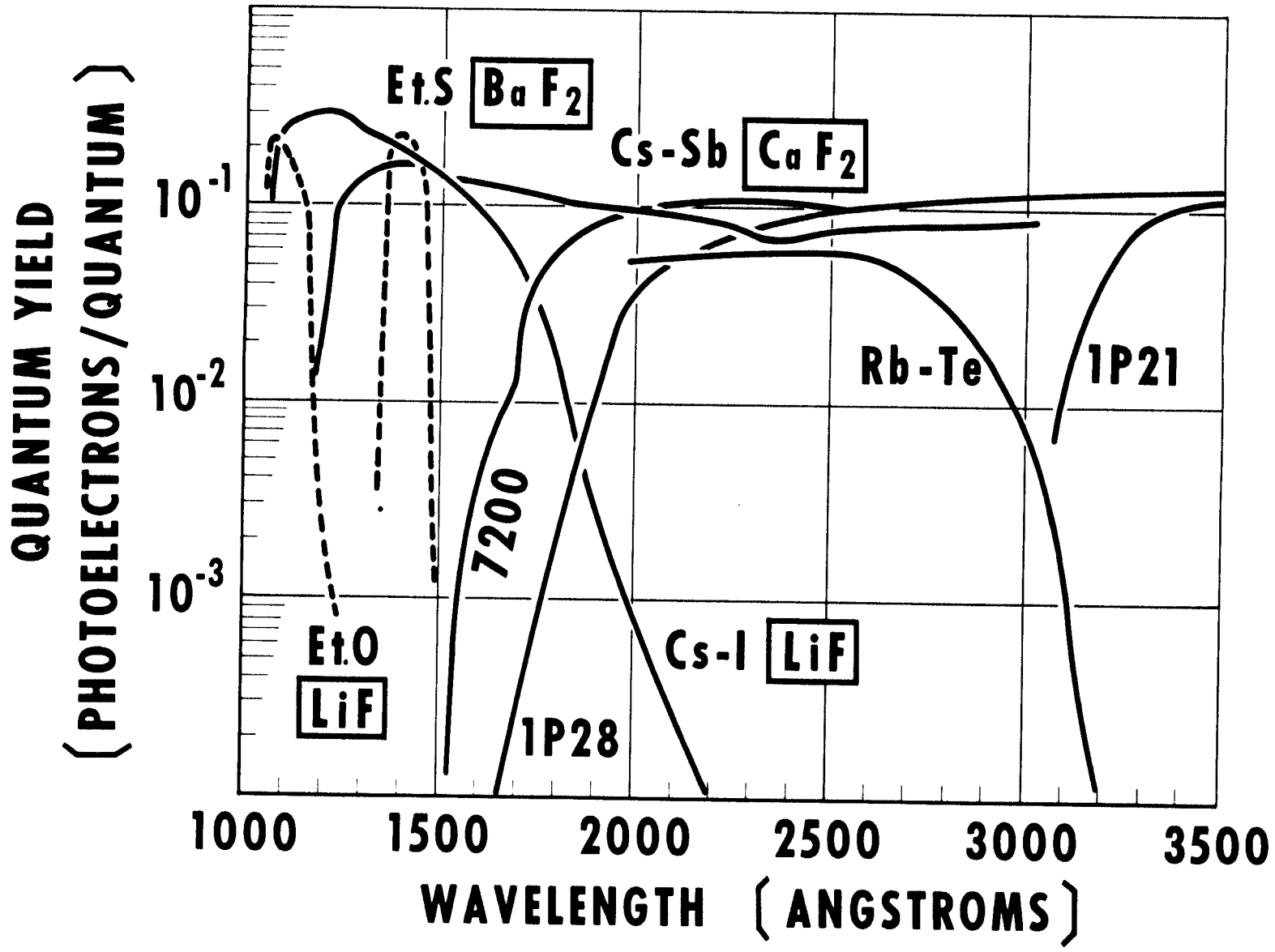
The curves marked 1P21, 1P28 and 7200 indicate the responses of currently available photomultipliers having cathodes of cesium-antimonide and envelopes of glass, 9741 and fused silica respectively.

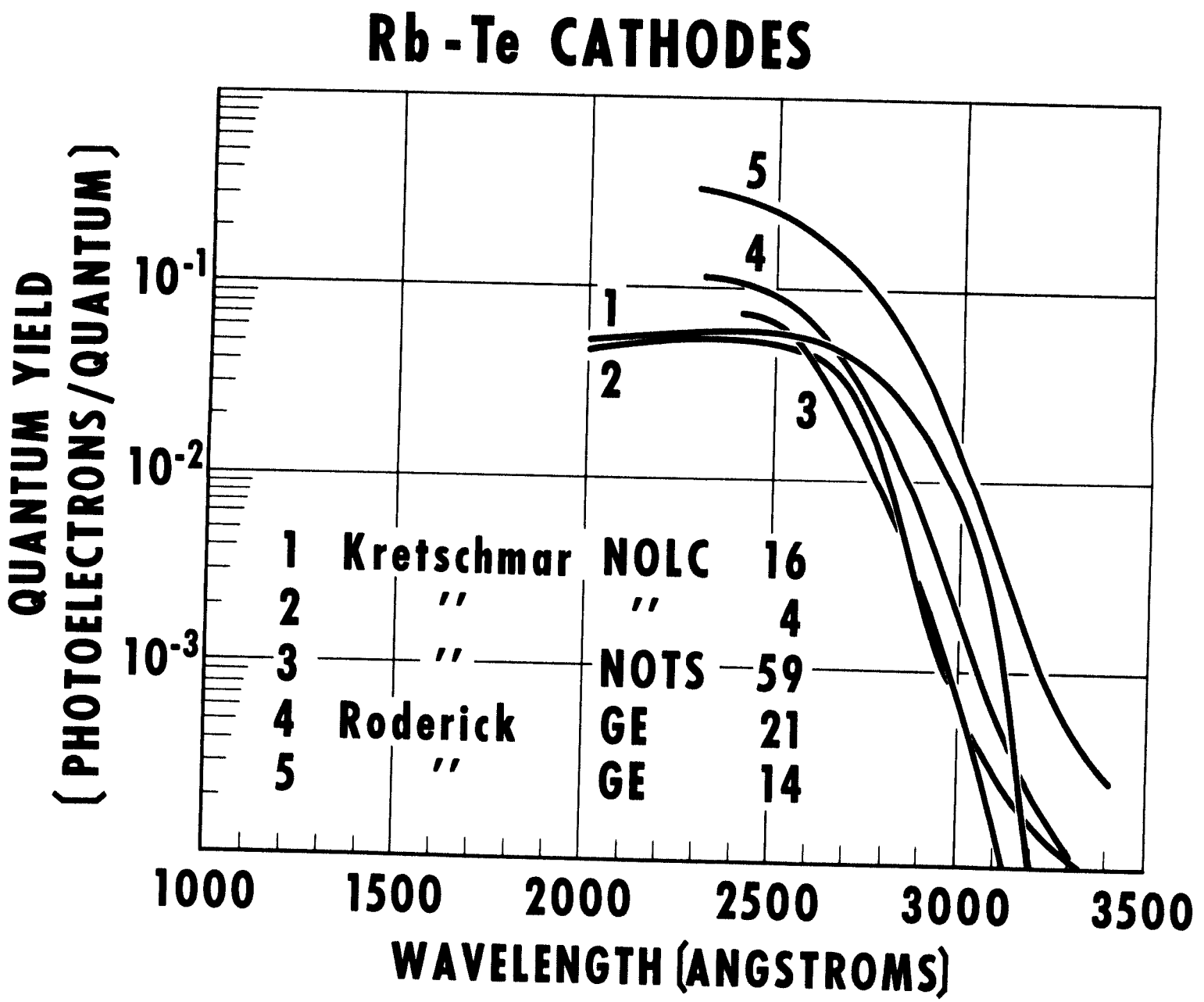
The curve marked Cs-Sb $\boxed{CaF_2}$ gives the measured response of a photomultiplier having in addition to a cesium-antimonide photocathode as above, a window of calcium fluoride crystal which extends its UV response down to 1250 Angstroms.

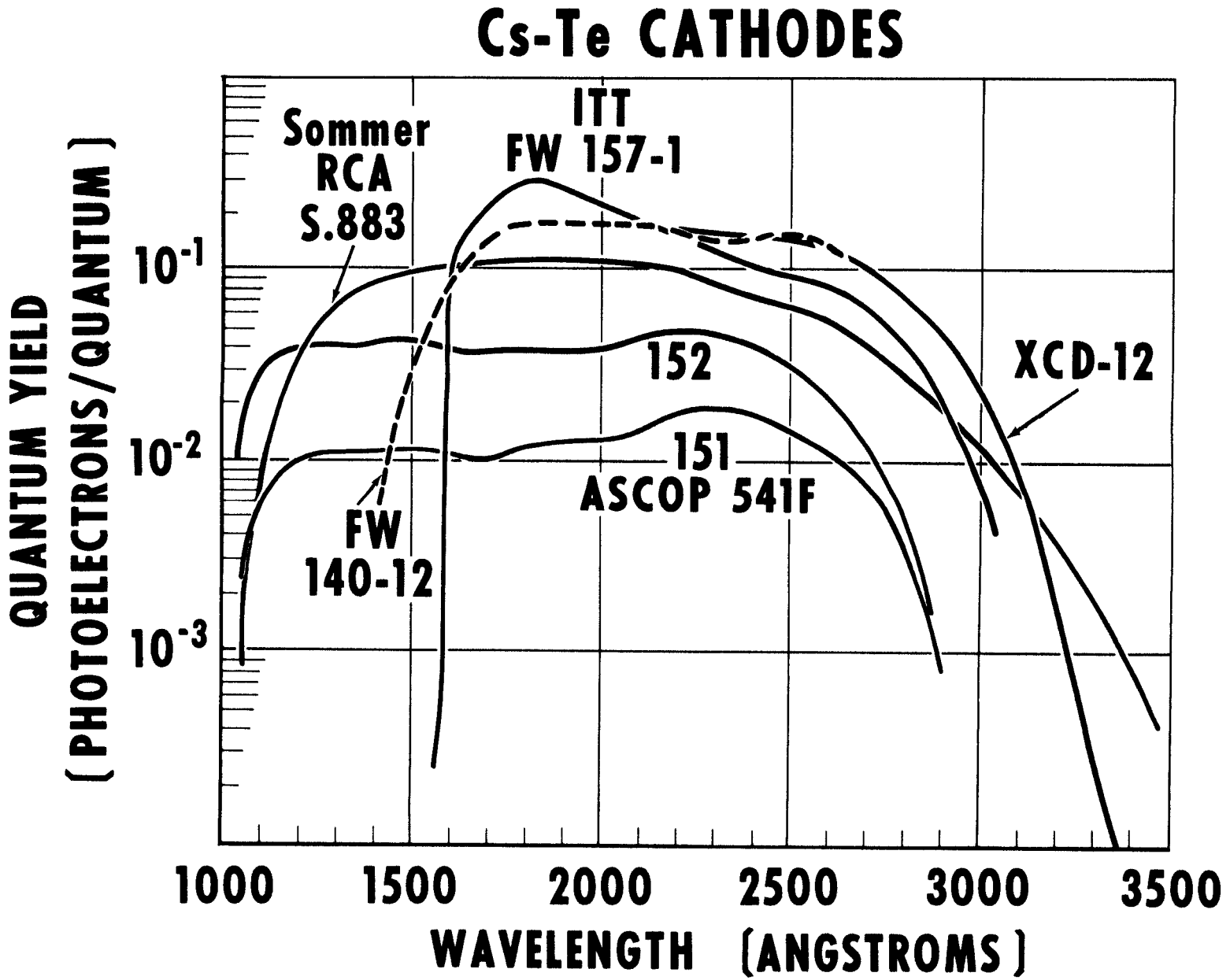
The curve marked Rb-Te represents a typical response of what is called a "solar blind" photocathode. This term refers to the fact that the photosurface is relatively insensitive to all visible and near ultraviolet wavelengths and therefore has very little response to the sun's light as seen through the earth s atmosphere.

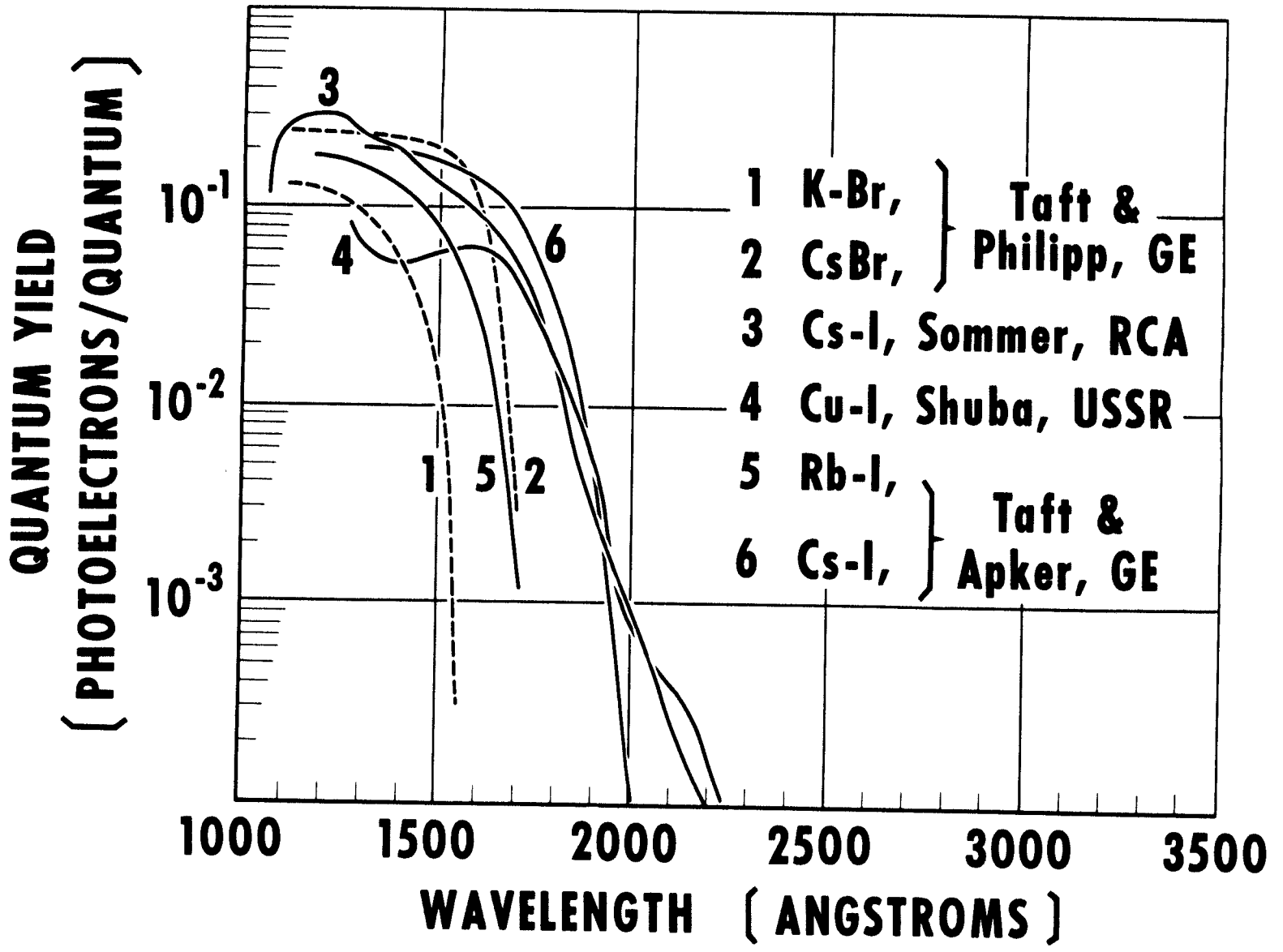
The curve marked Cs-I $\boxed{LiF}$ gives the response of a photosurface which rejects even more of the middle and near ultraviolet as well as the visible wavelengths.

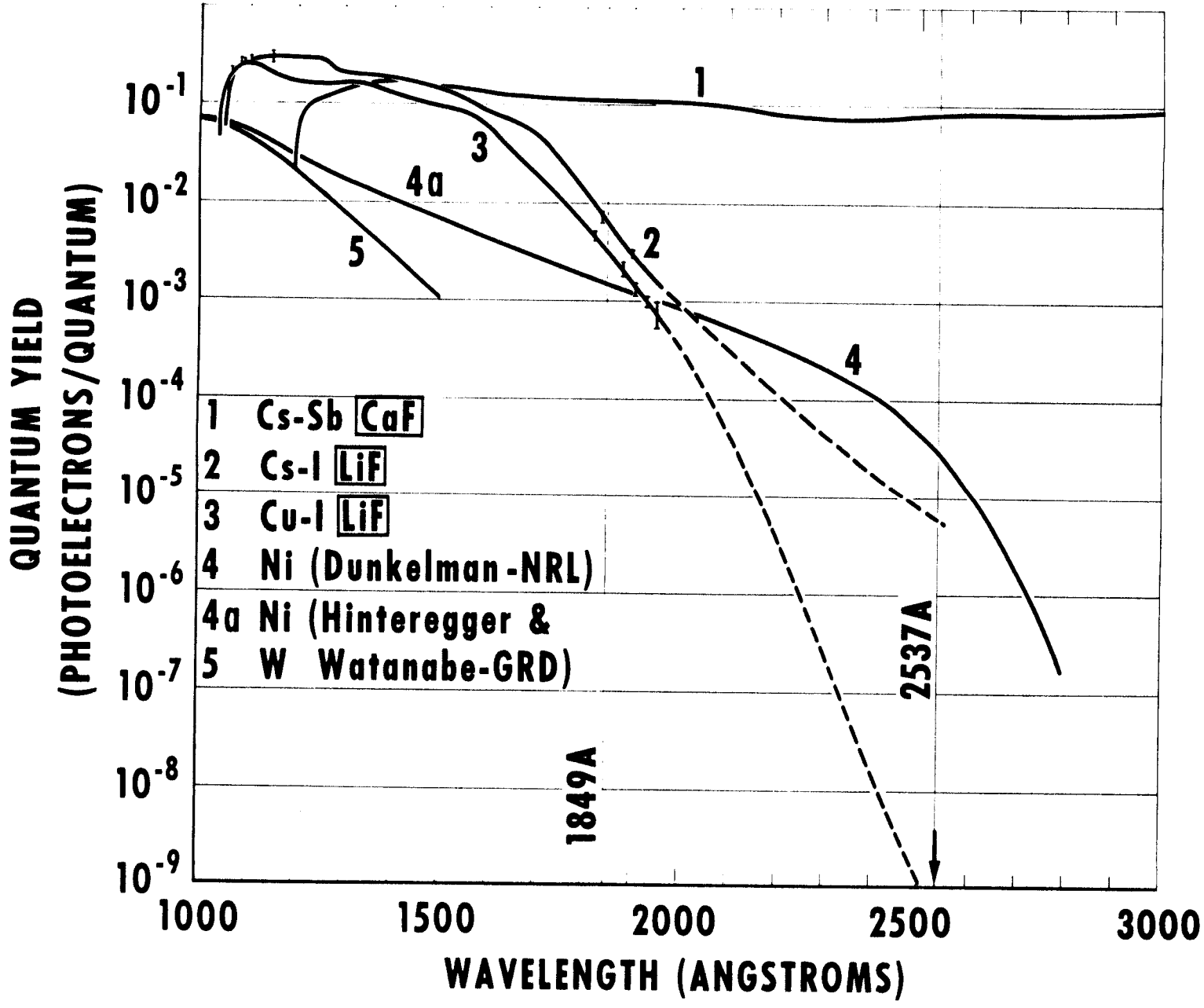
The two dashed curves represent the response of two photodetectors which operate not by photoelectric emission from a solid photocathode as in all of the above illustrations, but by photoionization of a gas cell. The curve marked EtS $\boxed{BaF_2}$ represents the response of ethylene sulfide gas in a chamber with a barium fluoride window. The other curve gives the ionization yield of ethylene oxide gas in an ion chamber with lithium fluoride windows.


QUANTUM YIELD
(PHOTOELECTRONS/QUANTUM)
10^{-1}
10^{-2}
10^{-3}
Et.S
BaF2
Cs-Sb
CaF2
Rb-Te
1P21
7200
Et.O
LiF
Cs-I
LiF
1P28
1000
1500
2000
2500
3000
3500
WAVELENGTH (ANGSTROMS)

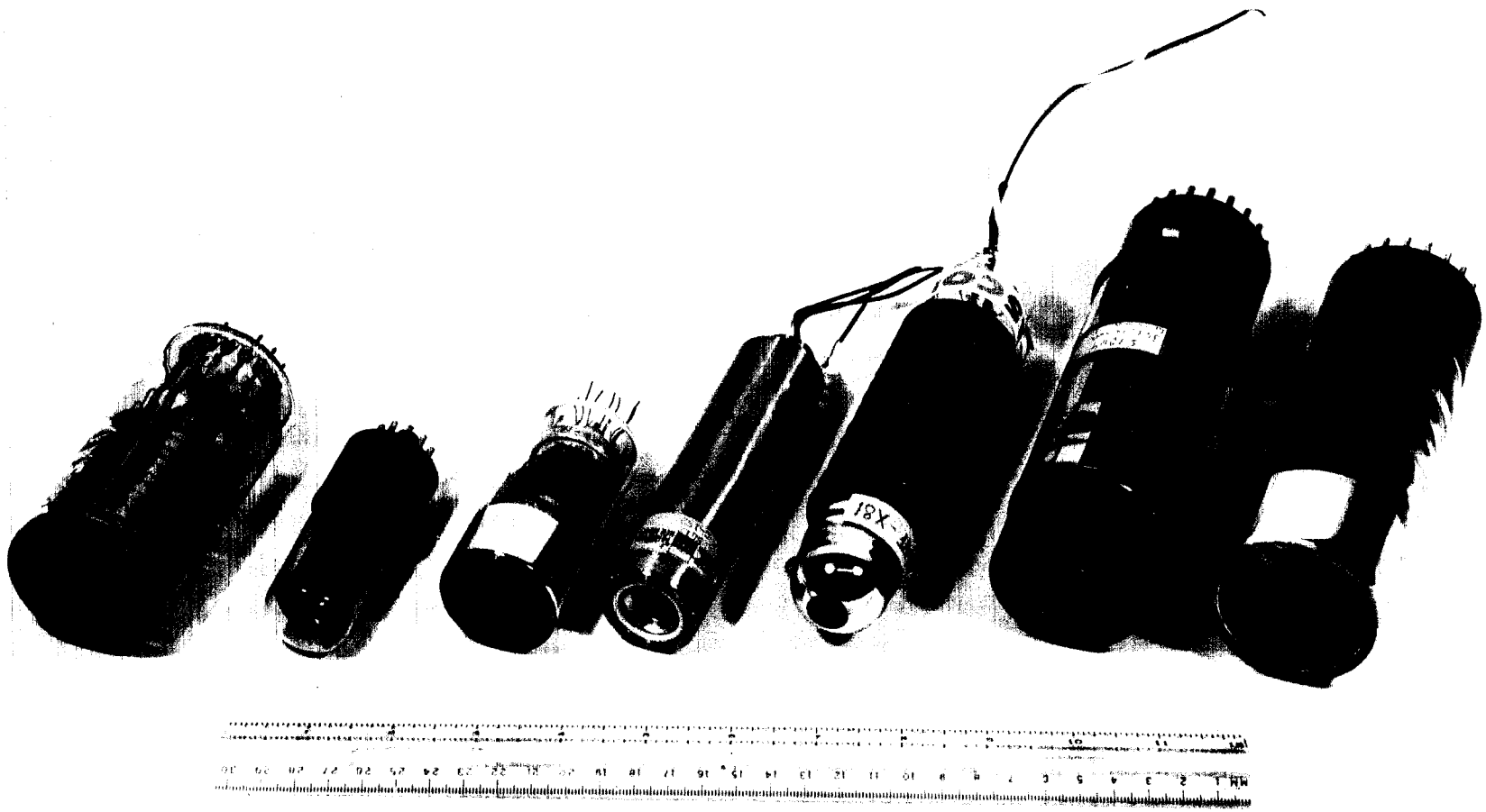

Rb-Te CATHODES
QUANTUM YIELD (PHOTOELECTRONS/QUANTUM)
10^{-1}
10^{-2}
10^{-3}
1000
1500
2000
2500
3000
3500
WAVELENGTH (ANGSTROMS)
1 Kretschmar NOLC 16
2 " " 4
3 " NOTS 59
4 Roderick GE 21
5 " GE 14


Cs-Te CATHODES
Sommer
RCA
S.883
ITT
FW 157-1
152
XCD-12
151
ASCOP 541F
FW
140-12
QUANTUM YIELD
(PHOTOELECTRONS/QUANTUM)
10^{-1}
10^{-2}
10^{-3}
1000
1500
2000
2500
3000
3500
WAVELENGTH (ANGSTROMS)


QUANTUM YIELD
(PHOTOELECTRONS/QUANTUM)
10^{-1}
10^{-2}
10^{-3}
1000
1500
2000
2500
3000
3500
WAVELENGTH (ANGSTROMS)
1 K-Br,
2 CsBr,
Taft & Philipp, GE
3 Cs-I, Sommer, RCA
4 Cu-I, Shuba, USSR
5 Rb-I,
6 Cs-I,
Taft & Apker, GE


QUANTUM YIELD
(PHOTOELECTRONS/QUANTUM)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
1000
1500
2000
2500
3000
WAVELENGTH (ANGSTROMS)
1 Cs-Sb CaF
2 Cs-I LiF
3 Cu-I LiF
4 Ni (Dunkelman-NRL)
4a Ni (Hinteregger &
5 W Watanabe-GRD)
1849A
2537A
1
2
3
4
4a
5

NASA G-62-541



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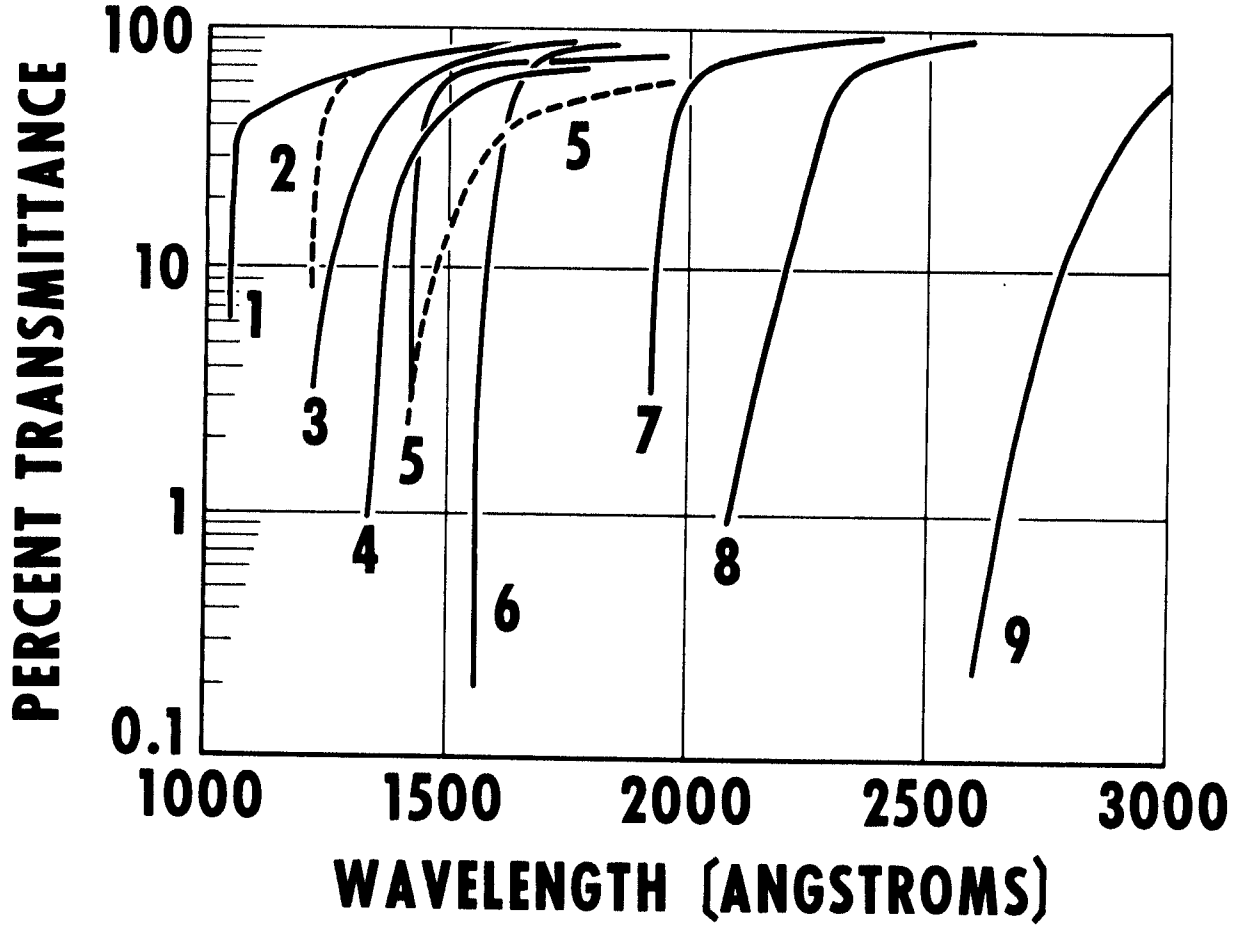
1 LiF 4 BaF_2 7 $NiSO_4(H_2O)_6$

2 CaF_2 5 SAPPHIRE 8 CORNING 9-54 (7910)

3 NaF 6 FUSED SILICA 9 CORNING 9700



WINDOW MATERIAL SHORT WAVELENGTH CUT-OFF (A)		CATHODE MATERIAL, LONG WAVELENGTH CUT-OFF (A)				
		Cu-I	Cs-I	Rb-Te	Cs-Te	Cs-Sb
GLASS	3220 3050					4600 7000
CORNING 9741	2160 1780			2700 3020	2700 3100	4600 7000
FUSED SILICA	1620 1550	1750 1950	1760 2000	2700 3050	2050 3050	4600 7000
SAPPHIRE	1460 1420	1640 1960	1680 2000	2700 3050	2780 3200	4600 7000
CaF_2	1300 1220	1420 1880	1460 1890	2700 3050	2700 3100	4600 7000
LiF	1120 1050	1420 1880	1460 1890	2700 3050	2600 2900	4600 7000

Upper Figure 50%, lower figure 1% maximum

FIGURE 9

CHARACTERISTICS OF A PHOTOIONIZATION CHAMBER FOR THE VACUUM ULTRAVIOLET

by

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Some of the varieties of photocathodes available in the vacuum and middle ultraviolet regions having been covered in the previous papers, WC 17 and WC 18, we now take up the photodetectors represented by the two narrow, dashed spectral response curves at the short wavelength end of Figure 1, which pictures the spectral region from 1000A in the vacuum UV to 3500A in the near UV. These relatively narrow responses are given by combining gases which will photoionize when exposed to photons with energies greater than 7 to 10 ev, with windows which will only pass photons with energies less than about the same 7 to 10 ev. When provision is made to collect the ions produced in the gas by incident photons the device is called an ion chamber.

Pictured in Figure 2 are some of the chambers which have been developed at Goddard Space Flight Center and are being used currently in both laboratory and rocket experiments.[1] These tubes consist of small ceramic shells, gold plated on the inside, fitted

with a central collecting wire electrode and having a window of suitable transmission properties. A completed crystal window chamber is shown in the center of the illustration, along with an unfinished tube at the left and a tube having an aluminum window, at the right, for use in the soft x-ray region.

The most desirable features of an ion chamber for use as a vacuum ultraviolet detector are: 1) its insensitivity to all longer wavelength stray light and backgrounds; 2) its relatively high sensitivity; 3) its stability in response, and 4) its comparatively small size.

Ion chambers and photon counters of a similar nature were first used in a series of rocket experiments at the Naval Research Laboratory in the 1950's.[2,3] From the experience gained in using these earlier photoionization detectors a new design for ion chambers was developed at Goddard, starting in February 1959, which has resulted in an ion chamber which continues to be small and rugged and has in addition both a very low electrical leakage and good vacuum sealing properties.

Figure 3 shows a section of the ion chamber, which has an inside diameter of about 3/4 inches and an inside length of about 1 inch. The shell is of alumina ceramic which has been made for us by the Coors Porcelain Co. in Golden, Colorado. The inside of the shell has several layers of metallic deposits ending with a gold plating. Around the central pin collector electrode where it passes through the shell is an electrical guard ring which is normally kept at ground potential.

The window is held onto a gold plated silver flange by several coats of an epoxy such as one of the Hysols. The flange is in turn fastened to the metal plated ceramic shell by soft solder. Window materials of LiF, CaF_2 and BaF_2 cleaved crystals have been used as well as some thin berylium and aluminum foils for the soft x-ray region.

After the windows are put on and baked, the tube is pumped through the long copper tubulation to a pressure of about 1×10^{-6} mm Hg, or until no more outgassing is evident.

The filling gas is then introduced and the tube pinched off and dipped in solder. The choice of the gas is determined by the spectral region of interest, that is by selecting a gas with a proper ionization potential. The filling pressure in the tubes discussed here range from 5 to 20 mm Hg and are determined empirically for each gas. The chamber having been filled and pinched off its ionization properties can be measured on a monochromator. Many of these chambers have been assembled by us in the last 2 years, but it is hoped that in the future complete tubes will become available from commercial sources. Properties of prime interest are the quantum efficiency at some given wavelength, the shape of the spectral response and the behavior of the chamber when operated in the gas gain region at high voltages.

Figures 4, 5 and 6 show the measured yields of five of the filling gas and window material combinations which have been used recently in some rocket experiments. Note that the wavelength scales are the same in each figure but have been shifted from

one figure to the next.

Figure 4 shows the response of ethylene oxide and carbon disulfide with LiF windows. Points are shown rather than curves so that any possible fine structure will not be concealed. The resolution of our monochromator was about 2-3 Angstroms. Note the high yields of CS_2, providing 50-60% quantum efficiencies.

Figure 5 shows the response of nitric oxide and acetone with CaF_2 windows. NO is known to have a great deal of fine structure in its ionization curve, only some of the features of which appear in this figure. Note that the acetone curve has only about a 50 A bandwidth.

Figure 6 shows ethyl sulfide combined with a BaF_2 window. Since these measurements were made we have found that in the several tubes which were made containing ethyl sulfide, the response has fallen off by a factor of 100 in the two months since filling. Evidently some more investigation of ethyl sulfide photoionization is necessary before it can be used successfully. The other chambers which have been mentioned have been found to hold up very well, although no very exhaustive tests have been made of their durability.

In a more compressed view of this spectral region the five ion chambers will look as shown in Figure 7. There is a considerable variation in both quantum yields and spectral response regions available. These response measurements were made on a 1 meter monochromator. The shape of the spectral response is determined by a comparison of the ion chamber response to a hydrogen arc lamp, with the response of sodium salicylate,

coated on the face plate of a photomultiplier, to the same hydrogen lamp. The fluorescence yield of sodium salicylate is assumed to be fairly constant over this wavelength region from 1000 to 1500 A.

Figure 8 shows the arrangement for making measurements with the ceramic ion chambers. From 20 to 60 volts gives a good flat plateau region for ion collection. The guard ring is normally kept grounded. Note that in addition to the ion chamber window there is a LiF window as part of the monochromator exit. The region between the two windows is evacuated by an external pumping system. The same monochromator flange is used for the sodium salicylate coated photomultiplier and the standard ion chamber which is used to determine the absolute ionization yields.

Figure 9 shows the schematic use of a standard ionization chamber which is used with nitric oxide to determine the absolute flux of the monochromator at Lyman Alpha, 1216 Angstroms. Utilizing the work of Watanabe[4] the absolute photoionization yield of NO is taken to be 81%.[5] The standard tube has a large volume and is operated at low pressures of about 6-8 mm Hg. Large flat plate collectors, rigidly mounted to avoid vibration pickup, provide efficient collection of all the photoions produced by the incident Ly Alpha light. The flat sodium salicylate response is used to transfer the quantum yield measurements from Ly Alpha to other selected wavelengths. This technique is also useful for calibration of the short wavelength photocathodes mentioned in paper WC 17

In many cases the incident flux is so small that it becomes desirable to operate with a detector that has a certain gain or multiplication factor in order to obtain measurable signals. If the voltage across the ion chamber is raised past the 20-60 volt plateau region the signal begins to increase as shown in Figure 10. Note that each tube has a region in which the gain is exponential but that at higher voltages the points begin to move above the straight line portion and the tube rapidly becomes unstable. With a good chamber,gains of 1000 can be reached with voltages of the order of 700-800 volts.

These ion chambers have been used in several rocket-borne experiments which have measured the flux from various night sky sources[6] and have also served as useful tools in laboratory spectroscopic studies. In the stellar flux measurements the signal measured, with the tube operated at a gain of about 1000, is on the order 10^{-12} amps. Because of the steep gain curves, the gain is of course very sensitive to voltage fluctuations. These ion chambers have also been operated as soft x-ray detectors by combing a gas filling of one atmosphere of Xenon with 1 mil thick berylium window. Such devices are useful in making solar x-ray measurements in the 1-8 A region.

In all of the ion chambers discussed here the short wave length limit has been determined by the transmission cutoff limits of one of three materials; LiF, CaF_2 or BaF_2 crystals. In addition to these materials, crystals of NaF and sapphire could also play a useful role in defining particular wavelength

response regions.

Finally included here is a table summarizing the most pertinent features of these ion chambers. The quantum efficiencies listed represent the variation over the peak response portion of the spectral response curves. The variation in ionization yield for a given type of gas and window combination will be about 10% from tube to tube, most of which is probably due to variations in the window transmittance.

NASA ION CHAMBERS

GAS FILLING	CHEMICAL FORMULA	WINDOW MATERIAL	SPECTRAL RESPONSE (ANGSTROMS)	Q.E.* (%)
Ethylene Oxide	$(CH_2)_2O$	LiF	1050-1180	10-20
Carbon Disulfide	CS_2	LiF	1050-1240	50-60
Acetone	CH_3COCH_3	CaF_2	1230-1290	8-10
Nitric Oxide	NO	CaF_2	1230-1350	10-30
Nitric Oxide	NO	LiF	1050-1350	10-50
Ethyl Sulfide	$(C_2H_5)_2S$	BaF_2	1350-1480	10-25

* Based on a value of 81% for NO at Ly-α

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Captions

Figure 1: Shown here are the spectral responses (photoelectric yield) of several photocathode materials in the vacuum and middle ultraviolet wavelength regions. The curves marked 1P21, 1P28 and 7200 indicate the responses of currently available photomultipliers having cathodes of cesium-antimonide and envelopes of glass, Corning 9741 and fused silica respectively. The curve marked Cs-Sb $\boxed{CaF_2}$ gives the measured response of a photomultiplier having in addition to a cesium-antimonide photocathode as above, a window of calcium fluoride crystal which extends its UV response down to 1250 Angstroms. The curve Marked Rb-Te represents a typical response of what is called a "solar blind" photocathode. The curve marked Cs-I $\boxed{LiF}$ gives the response of a photosurface which rejects even more of the middle and near ultraviolet as well as the visible wavelengths. The two dashed curves represent the response of two photodetectors which operate not by photoelectric emission from a solid photocathode as in all of the above illustrations but by photoionization of a gas cell. The curve marked EtS $\boxed{BaF_2}$ represents the response of ethylene sulfide gas in a chamber with a barium fluoride window. The other curve gives the ionization yield of ethylene oxide gas in an ion chamber with lithium fluoride windows. Such photoionization

chambers with their very narrow response regions and high quantum yields have proved very useful in vacuum ultraviolet spectroscopy and stellar astronomy from rockets.

Figure 2: Photograph of three NASA ceramic ion chambers. At left is an unfinished chamber with a LiF crystal window and a gold plated window flange lying in front of the ceramic shell. In the center is a completed ion chamber. At the right is an ion chamber with an aluminum window for use in the soft x-ray region.

Figure 3: Cross section of a ceramic ion chamber. The alumina ceramic shell is coated on the inside with four metallic layers as shown.

Figure 4: Quantum yield of ethylene oxide and carbon disulfide ion chambers with LiF windows.

Figure 5: Quantum yield of nitric oxide and acetone ion chambers with CaF_2 windows.

Figure 6: Quantum yield of an ethyl sulfide ion chamber with BaF_2 window.

Figure 7: Ion chamber spectral response for the region 1000-1500 Angstroms. Smoothed curves are shown although a certain amount of fine structure is obscured in

this way. Note the high quantum yields and narrow response regions of some of these photoionization detectors.

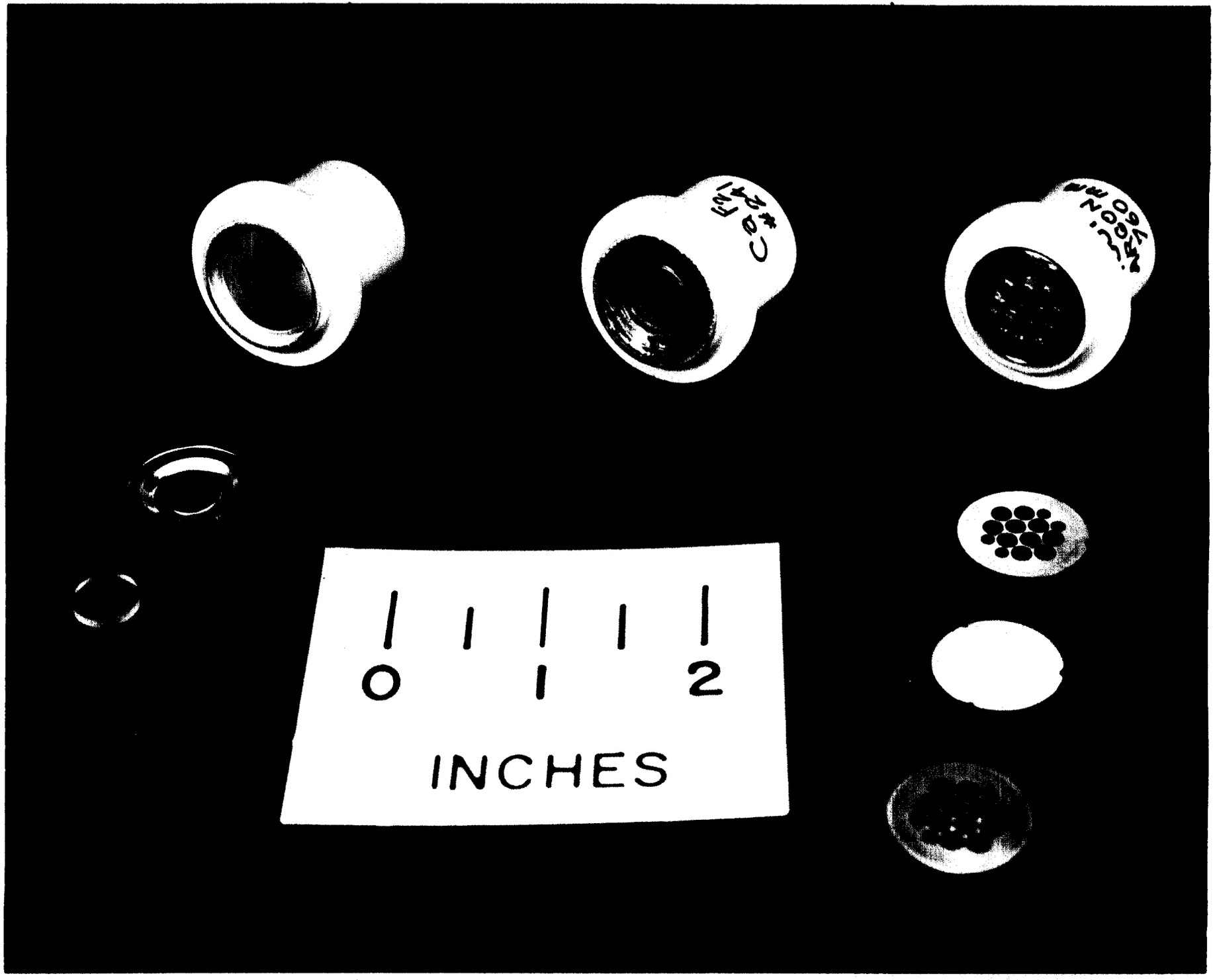
Figure 8: Schematic of ceramic ion chamber operation for calibration. The center pin is positive, the shell is negative. The light comes from the monochromator at left, passing through an exit window of LiF, an evacuated region between the two windows and into the ion chamber.

Figure 9: Schematic of the standard ion chamber operation for calibration. The metal plate collecting electrodes are mounted rigidly, a metal shield around the glass envelope keeps down capacitive pick up.

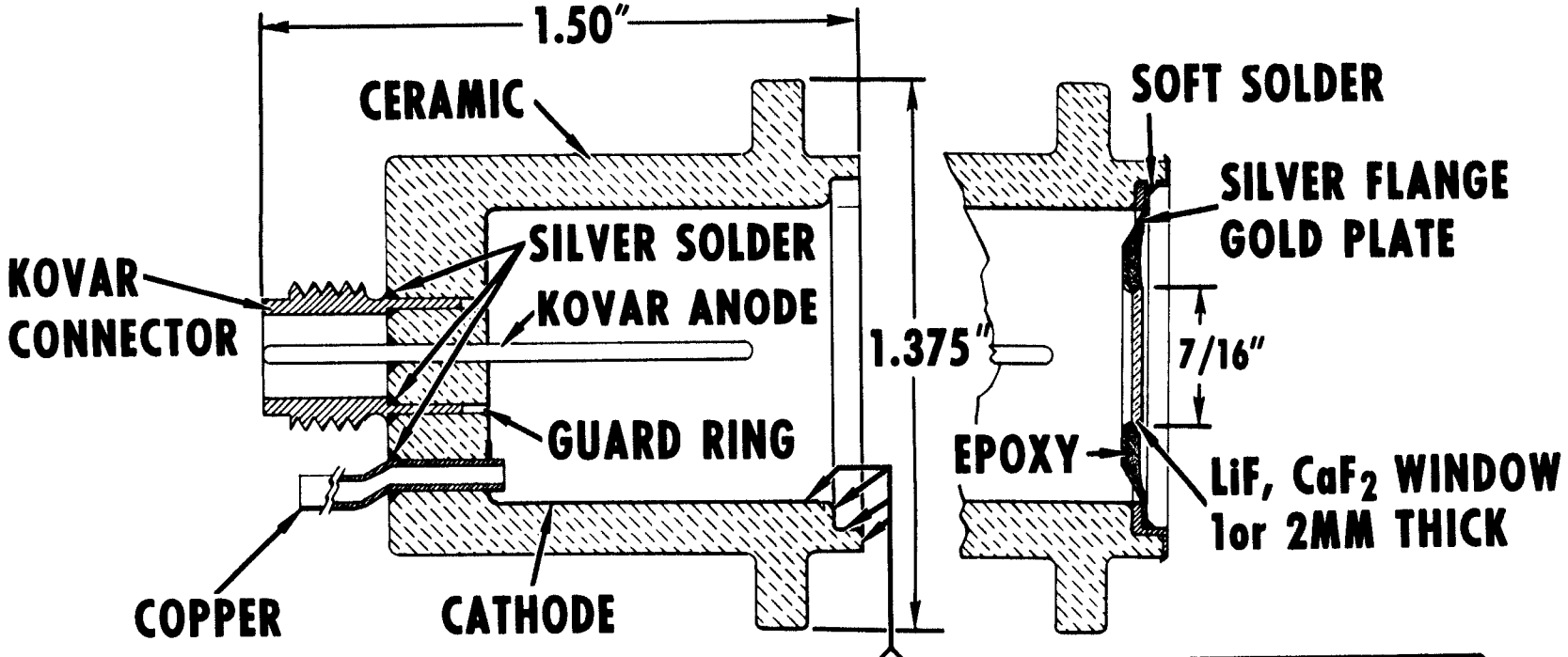
Figure 10: Ion chamber gas gain vs voltage. Each ion chamber exhibits a region of exponential gain through the straight line portion of the curve but as the voltage is increased a region of instability is reached.

FIGURE 1

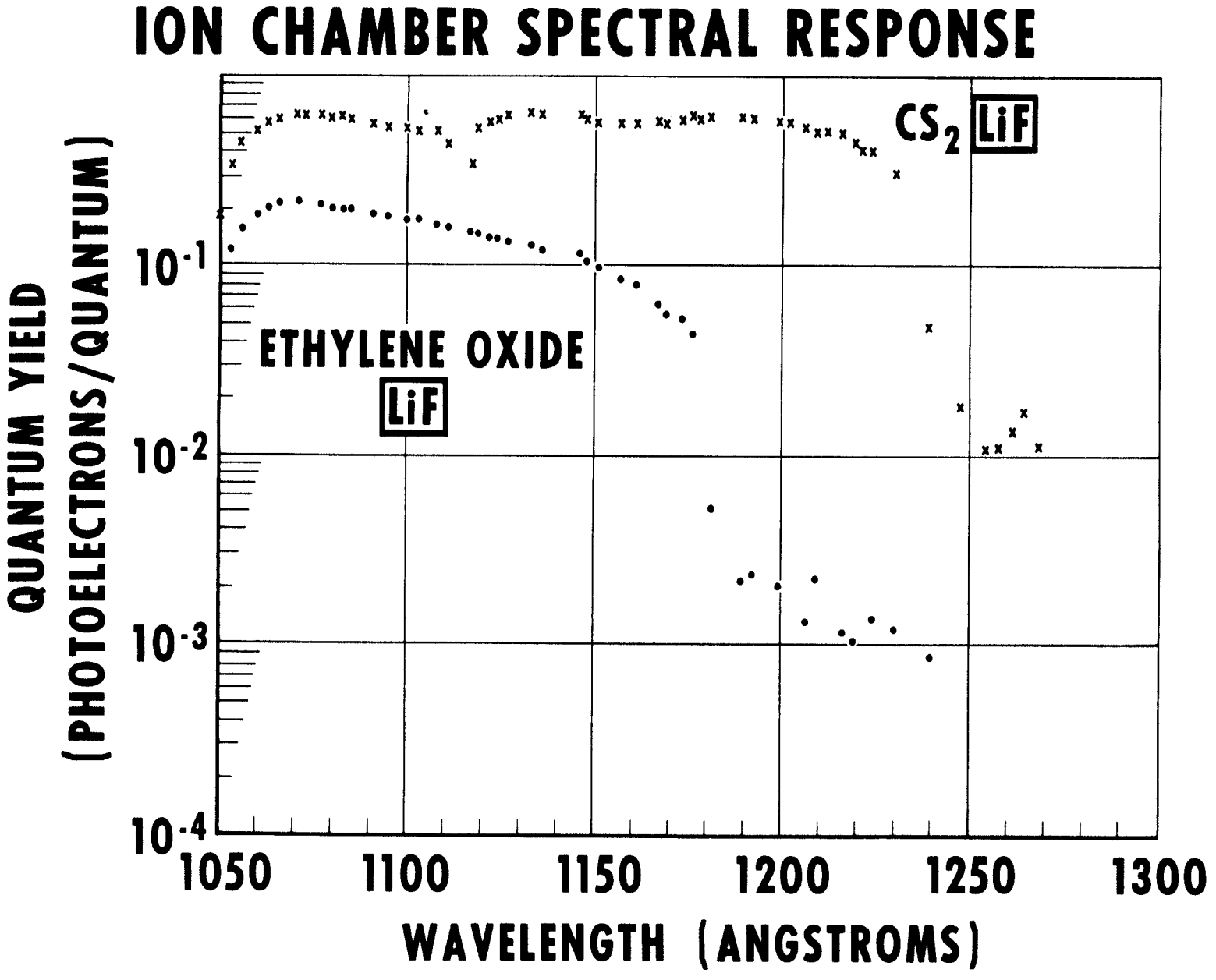
See Figure 1 of Paper WC 17


0
1
2
INCHES

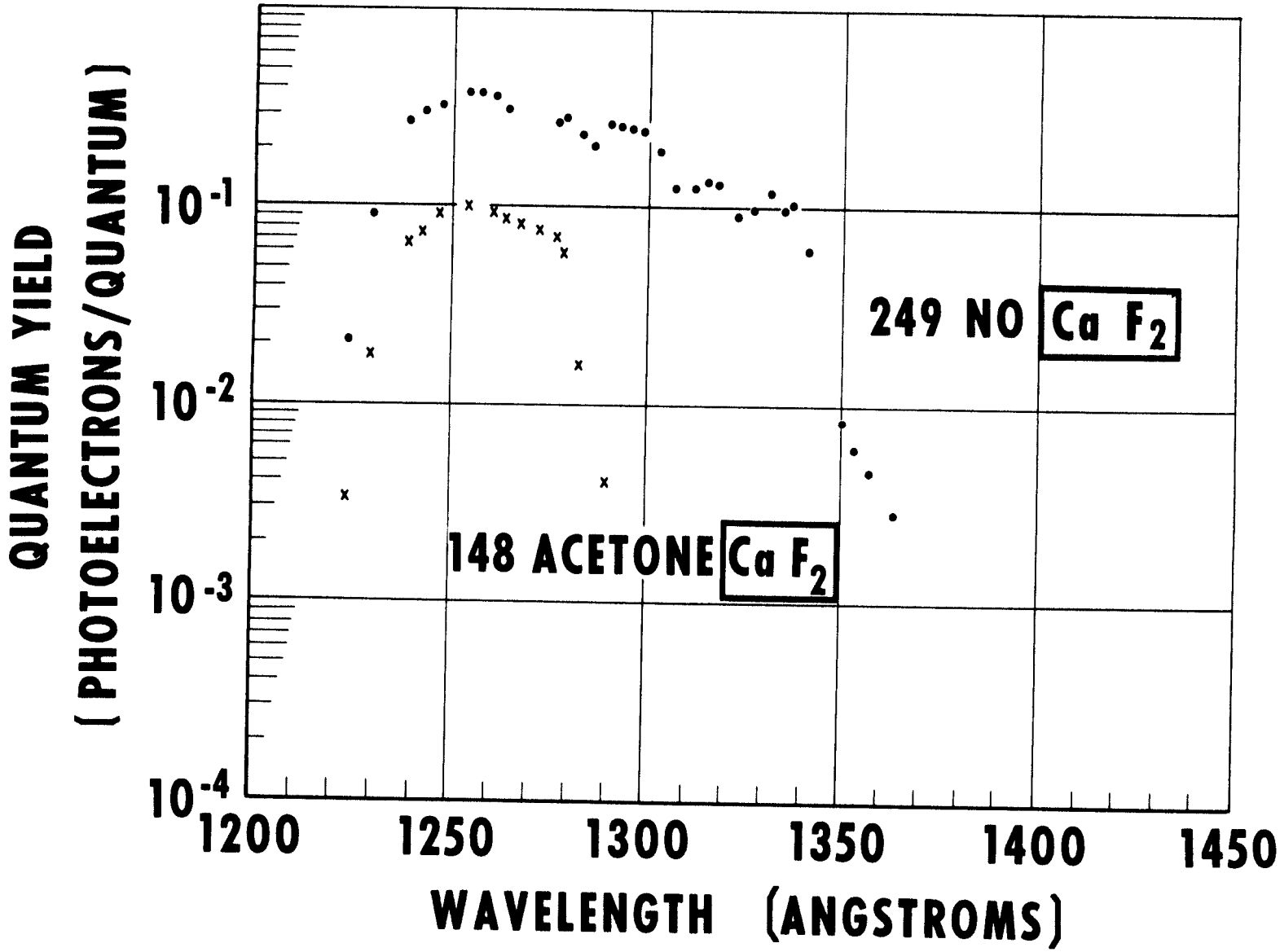
NASA
ION CHAMBER

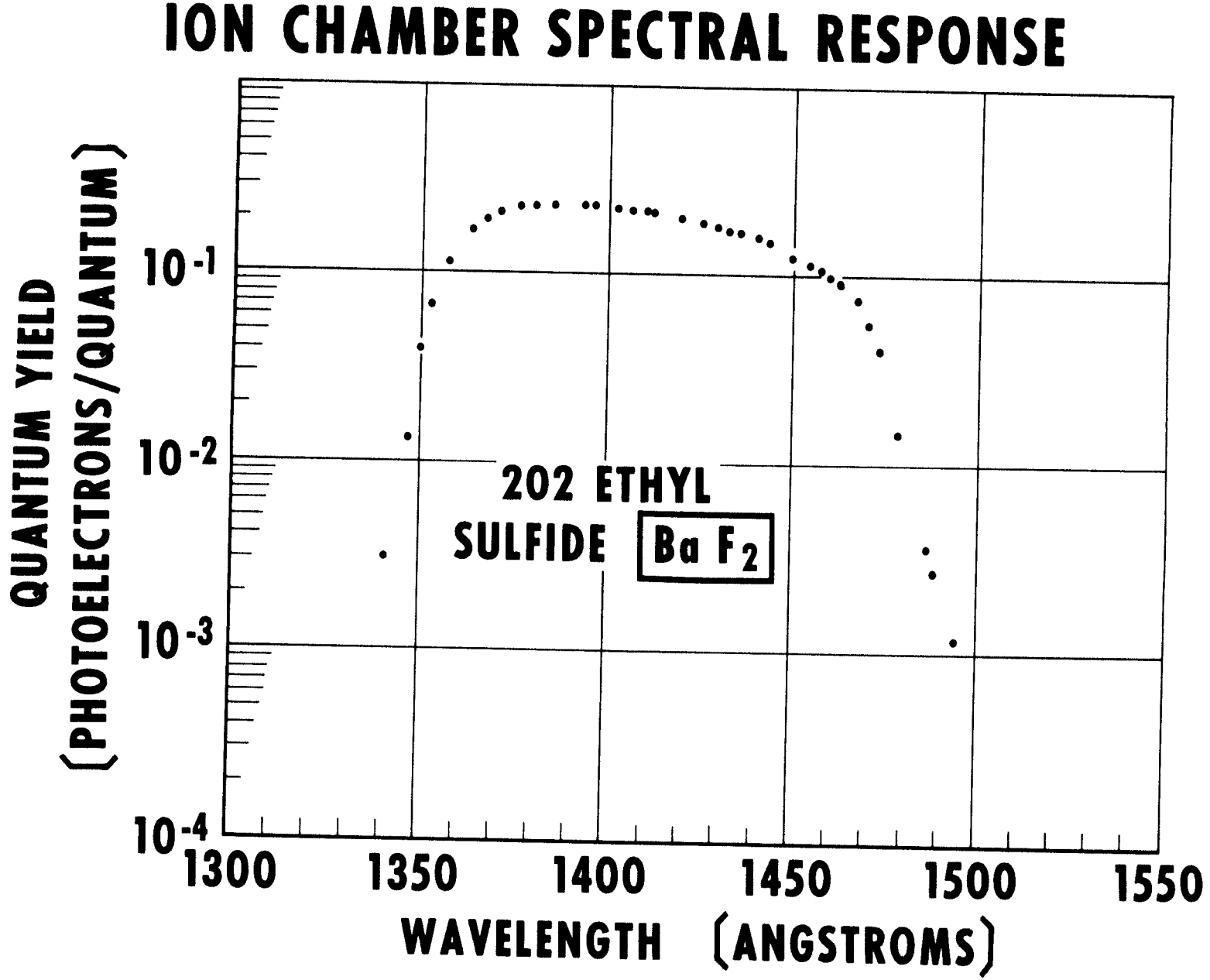


1. Mo Mn METALIZING
2. NICKEL PLATING (FLASH)
3. COPPER PLATING 0.0005"
4. GOLD PLATE 0.0004" AND SINTER

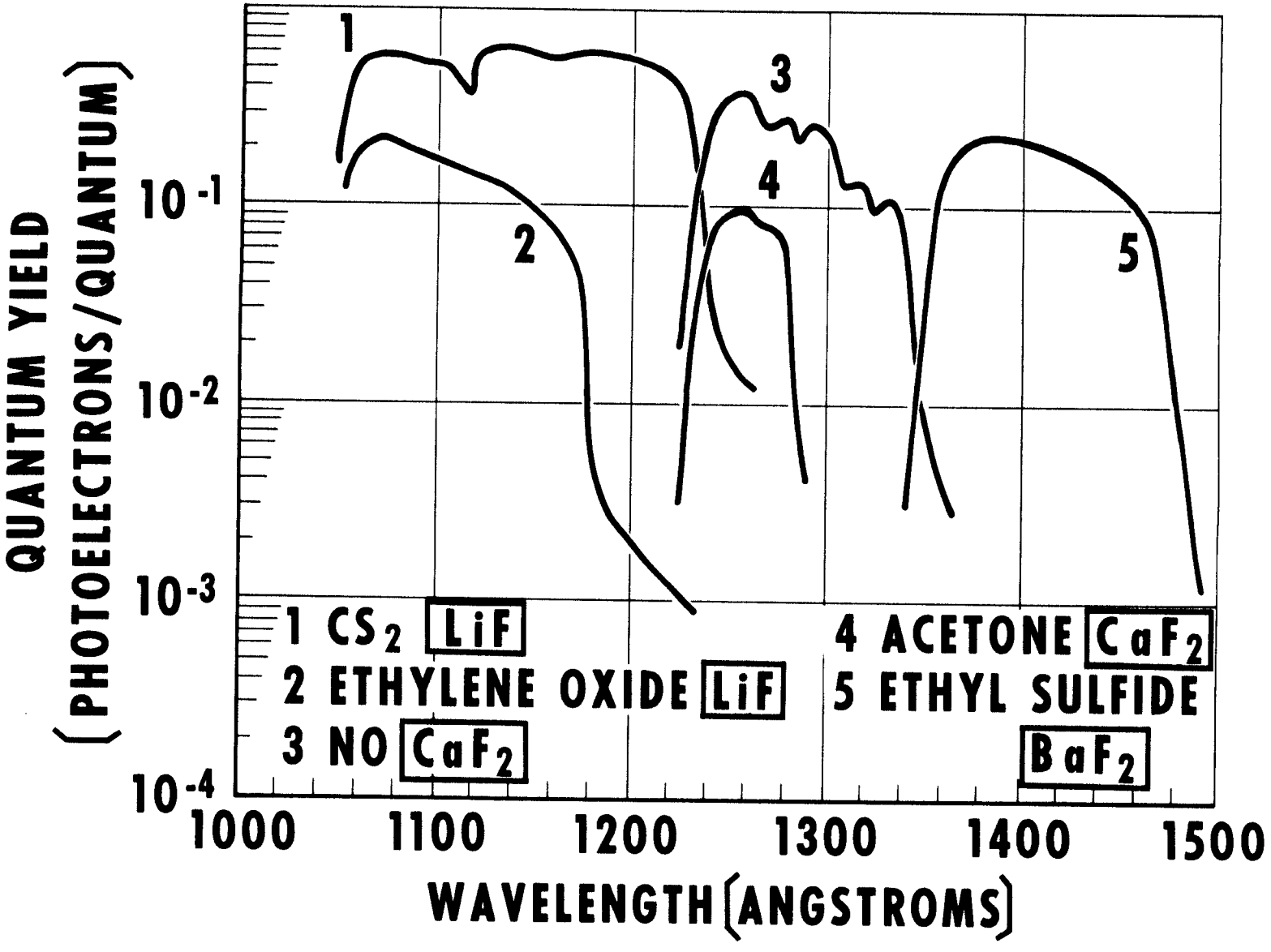

ION CHAMBER SPECTRAL RESPONSE
QUANTUM YIELD
(PHOTOELECTRONS/QUANTUM)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
CS_2 LiF
ETHYLENE OXIDE
LiF
1050
1100
1150
1200
1250
1300
WAVELENGTH (ANGSTROMS)

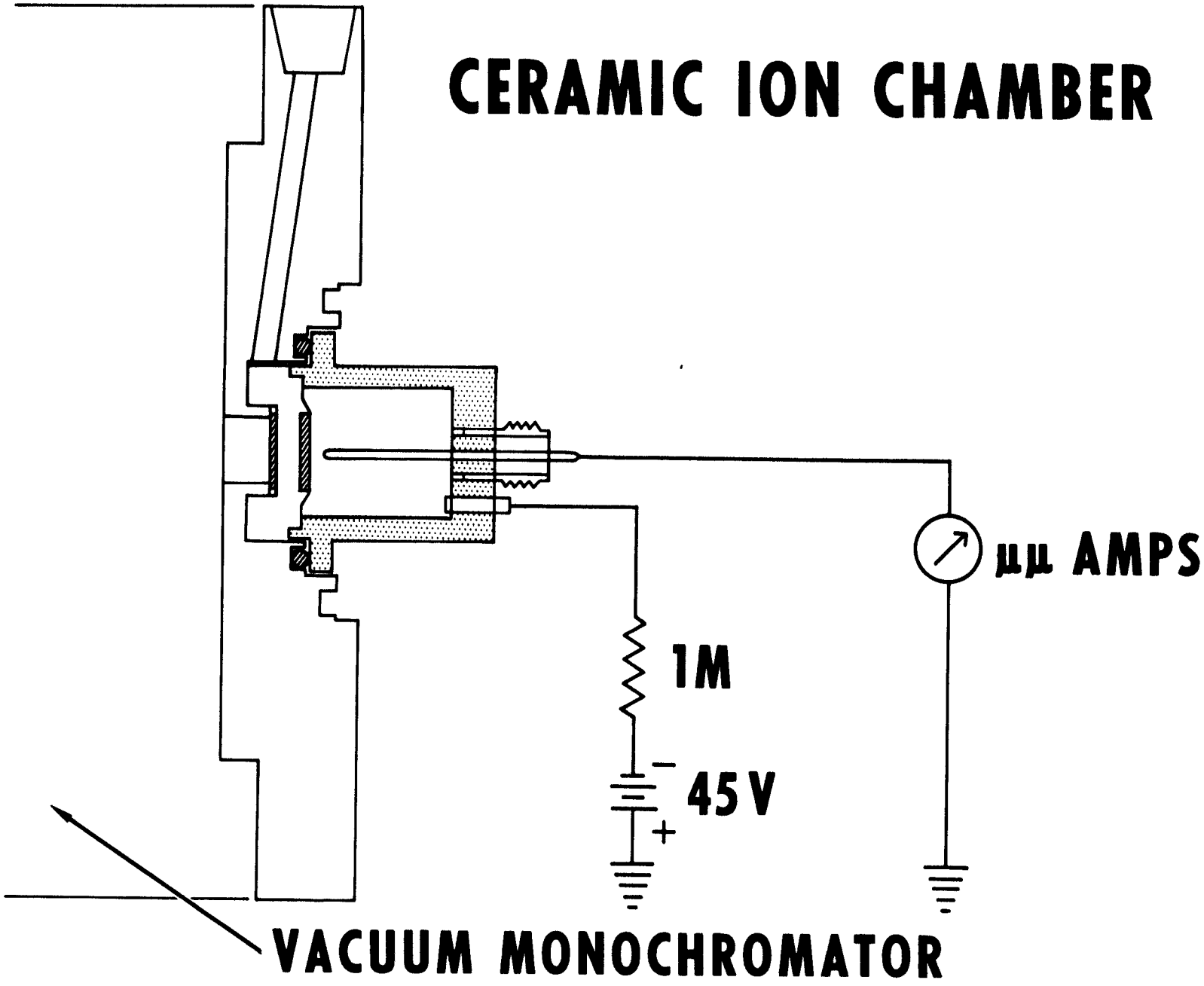
ION CHAMBER SPECTRAL RESPONSE



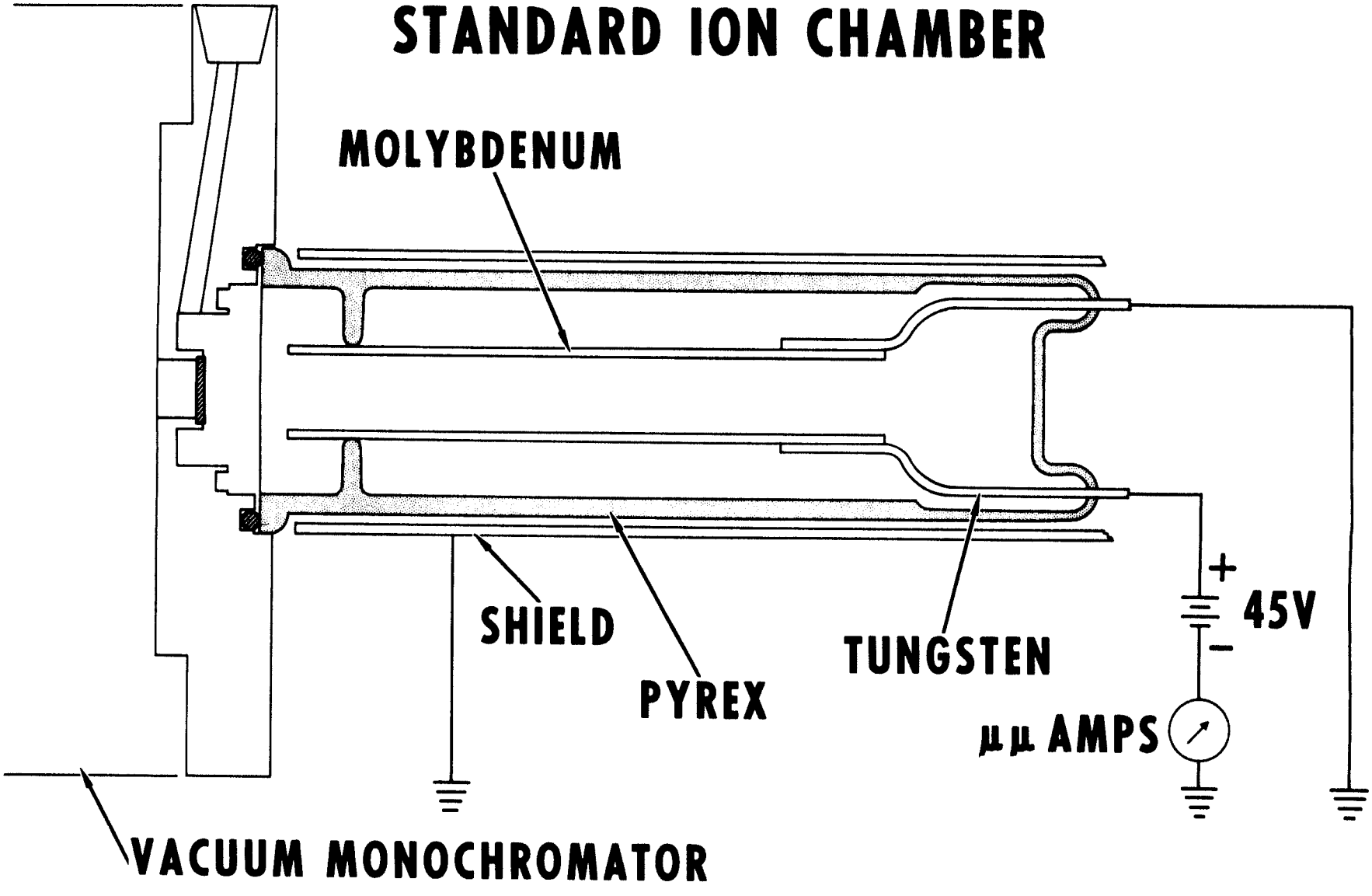

ION CHAMBER SPECTRAL RESPONSE
QUANTUM YIELD (PHOTOELECTRONS/QUANTUM)
10-1
10-2
10-3
10-4
202 ETHYL SULFIDE
Ba F2
1300
1350
1400
1450
1500
1550
WAVELENGTH (ANGSTROMS)

ION CHAMBER SPECTRAL RESPONSE




CERAMIC ION CHAMBER
μμ AMPS
1M
45V
VACUUM MONOCHROMATOR

STANDARD ION CHAMBER



ION CHAMBER GAIN vs VOLTAGE